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Indian Standard

SPECIFICATION FOR CAPACITORS FOR INDUCTIVE HEAT GENERATING PLANTS OPERATING AT FREQUENCIES BETWEEN 40 AND 24 000 Hz

UDC 621·319·44 : 621·365·58

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

February 1980

AMENDMENT NO. 1 MAY 1984

TO

IS : 9251 - 1979 SPECIFICATION FOR CAPACITORS FOR INDUCTIVE HEAT GENERATING PLANTS OPERATING AT FREQUENCIES BETWEEN 40 AND 24 000 Hz

Alteration

(*Page 10, clause 8.1.2.1*) - Substitute the following for the existing clause:

'8.1.2.1 *Sampling plan and criteria for acceptance tests* - The sampling plan and criteria for acceptance shall be as agreed to between the manufacturer and the user.'

(ETDC 29)

Reprography Unit, ISI, New Delhi, India

Indian Standard

SPECIFICATION FOR CAPACITORS FOR INDUCTIVE HEAT GENERATING PLANTS OPERATING AT FREQUENCIES BETWEEN 40 AND 24 000 Hz

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(*Continued on page* 2)

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Indian Standard

SPECIFICATION FOR CAPACITORS FOR INDUCTIVE HEAT GENERATING PLANTS OPERATING AT FREQUENCIES BETWEEN 40 AND 24 000 Hz

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 August 1979, after the draft finalized by the Power Capacitors Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 In preparing this standard, assistance has been derived from the following:

IEC Pub 110 (1973) Recommendation for capacitors for inductive heat generating plants operating at frequencies between 40 and 24 000 Hz. International Electrotechnical Commission.

BS 1650 : 1971 Capacitors for connection to power frequency systems. British Standards Institution.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard specifies the safety and performance requirements, and methods of tests for capacitors for power factor correction of inductive heat generating plants and also for otherwise modifying the characteristics, such as voltage and frequency of a circuit. It also provides guidance for installation and operation of such capacitors. The capacitors covered by the standard shall be suitable for operation at frequencies between 40 and 24 000 Hz.

1.2 This standard applies to the indoor capacitor units banks complete with accessories which are intended:

a) for parallel and series connection, and

b) for connection to an adjustable (variable) ac voltage system.

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*Rules for rounding off numerical values (*revised*).

1.3 This standard does not cover the following types of capacitors:

a) Capacitors which are directly connected to ac low, medium and high voltage distribution network;

b) Capacitors intended for control, protection and measurement purposes (for example, coupling capacitors and the like of it);

c) Small capacitors as used for fluorescent and discharge lamps and for electric sign circuits; and

d) Capacitors for motor starting application and the like of it.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS : 1885 (Part XLII)-1977* shall apply.

3. RATING

3.1 Preferred Rated Outputs — The preferred rated outputs of capacitors units shall be 200 and 400 kVAr.

4. SERVICE CONDITIONS

4.1 Ambient Temperatures — The following temperature limits are specified:

a) For air-cooled self-ventilated capacitors	50°C *Max*
b) For air-cooled forced-ventilated capacitors:	
Inlet temperature of cooling air	50°C *Max*
Outlet temperature of cooling air	55°C *Max*

The outlet temperature of cooling air shall not rise by more than 5°C above the inlet temperature.

c) For water-cooled capacitors:	
Inlet temperature of cooling water	50°C *Max*
Outlet temperature of cooling water	55°C *Max*

The outlet temperature of cooling water shall not rise by more than 10°C over the inlet temperature.

The air temperature around the capacitor shall not exceed 55°C and shall not rise by more than 10°C above the ambtent temperature.

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*Electrotechnical vocabulary: Part XLII Power capacitors.

4.2 Altitude — Unless otherwise specified, capacitors shall be suitable for operation on sites at altitudes up to and including 1 000 metres above mean sea level.

5. SAFETY REQUIREMENTS

5.1 Discharge Device

5.1.1 All capacitor equipment shall be provided with a directly connected discharge device, unless it is connected directly to other electrical equipment providing a discharge path without a disconnecting switch, fuse cut-out, or series capacitor interposed.

5.1.2 The discharge device (or the electrical equipment mentioned in **5.1.1**) shall reduce the residual voltage from the peak value of the rated voltage *V*n to 50 V or less within a given time after the capacitor is disconnected from the source of supply. This time is 1 minute for capacitors of rated voltage up to and including 660 V, and 5 minutes for capacitors of rated voltage above 660 volts.

NOTE — When capacitor units are connected in series, discharge devices fitted to each unit may not be adequate to ensure compliance with the requirements of **4.1.2** owing to the cumulative effect of the residual voltages. If the supply voltage is so high that this occurs, then an additional external discharge device may be necessary, and should be connected directly across the capacitor bank.

5.1.3 When capacitors are required to be switched off and on at very short intervals, arrangements shall be made so that, at the time of re-application of the voltage, the voltage at the terminals of the capacitors shall be not more than 10 percent of its rated rms voltage.

5.1.4 A discharge device is not a substitute for the device intended for short-circuiting the capacitor terminals together and to earth before handling.

NOTE — A residual charge may some times be left on interconnections of series-connected capacitors due to blown fuses, interrupted internal connections, or non-linear behaviour of the dielectric resulting from overstressing. These interconnections, therefore, are to be short-circuited to earth before handling.

5.2 Earth Connection — If the metallic container of a capacitor is at earth potential in normal service, it shall be possible to connect it to earth in a reliable way, and the earth connection shall be clearly marked with the symbol ' ⏚ '.

5.3 Signalling and Control Equipment — If electrical signalling or protective devices, for example, thermocouples having circuits electrically insulated from the power circuits of the capacitor, are attached to, or built into the capacitor, the rated insulation voltage value between these circuits and that of the capacitor shall be equal to the rated insulation voltage of the equipment.

5.4 Cooling Ducts — The manufacturer shall ensure that the cooling ducts of water-cooled capacitors shall be capable of withstanding any hydrostatic pressure likely to be encountered in normal service.

5.5 Other Safety Requirements — Capacitors shall comply with the relevant general safety regulations for power installation, that is, Indian Electricity Rules, 1956.

5.5.1 The high frequency capacitor installations shall normally be enclosed behind a metal screen wall and this screen wall shall also be securely earthed.

5.5.2 If a water connection is made it shall be separated and insulated adequately where it comes off the capacitor assembly.

5.5.3 In general the contact surfaces of a connection in a high frequency capacitor installation should be made larger than equivalent surfaces for power capacitors at mains frequencies to allow for the skin effects at high frequencies.

5.5.4 If a capacitor has different sections in one common housing with different voltage ratings, then:

a) the lowest rated voltage section shall have a minimum insulation level corresponding to the commonly rated voltage.

b) the insulation level between any two sections shall correspond to the highest insulation level coming under most unfavourable working conditions between any two sections.

5.5.5 An internal fuse, if used, in a capacitor shall:

a) not blow upon an external short circuit under peak volt conditions at the external terminals,

b) blow upon an internal short circuit, and

c) not blow under normal working voltages.

5.5.6 *Behaviour at Switching*

5.5.6.1 The capacitor shall be so designed that it is back-arc free and shall discharge down to 0·1 rated voltage before reswitching.

5.5.6.2 The greater frequency of switching shall be understood to be 100 switching-in and 100 switching-out operations in a working day. This number may also be mutually agreed between the purchaser and the manufacturer.

6. MARKING

6.1 Rating Plate

6.1.1 The following information shall be given on the rating plate of each capacitor unit:

a) Reference to Indian Standard (as 'Ref ISS 9251');

b) Manufacturer's name and/or trade-mark;

c) Manufacturer's identification number;

d) Rated output in kVAr or rated capacitance in µF;

e) Rated voltage V_n in V or kV;

f) Rated frequency in Hz or kHz;

g) Rated current;

h) Cooling and temperature category, which shall be indicated in the following order:

  1) Type of cooling (self or forced ventilated),
  2) Lower category temperature,
  3) Upper category temperature,
  4) Inlet or outlet as applicable (forced cooled capacitor only),
  5) Rate of flow of cooling medium (forced cooled capacitor only);

j) Connection symbol;

k) Number of phases;

m) Insulation level;

n) Discharge device;

p) Total mass;

q) Reference to self-healing design, for example, SH; and

r) Reference to internal fuses.

NOTE 1 — For small units where it is impracticable to indicate all the above items on the rating plate, items (j), (k) and (m) may be stated in an instruction sheet. The rating plate shall bear a reference to this sheet.

NOTE 2 — Further information which is important for the safety of persons or equipment shall be stated either on the rating plate or in an instruction sheet and the rating plate shall bear reference to this sheet.

NOTE 3 — A warning instruction stating 'DISCHARGE CAPACITOR BANKS BEFORE HANDLING' shall be prominently marked in red.

NOTE 4 — Capacitor banks shall be provided with a rating plate so attached as to be visible from the exterior of the housing or enclosure of the bank. It shall include items given in **6.1.1** as relevant to the rating of complete bank.

6.1.1.1 For multi-step capacitors, designation of step power or step capacitances at the terminals shall be shown in a separate rating plate.

6.1.1.2 For capacitors designed to operate at variable frequencies, the safe load may be designated, for example, 500 Hz/300 A to 900 Hz/450 A. This data should cover the frequency zone.

6.1.2 The type of connection shall be indicated by the following symbols:

△ : Delta

⅄ : Star

ᛦ : Star, neutral brought out

\\\ : Three sections without internal interconnections.

6.1.3 The insulation level shall be marked by means of two numbers separated by a stroke, the first number giving the rms value of the power frequency test voltage in kV and the second number giving the crest value of the impulse test voltage in kV peak (for example, 28/75). For units which are not intended for exposed installations, the second number is replaced by a dash (for example, 28/-).

6.2 Terminal Markings

6.2.1 The terminals of three-phase capacitors having three terminals only, and of single-phase capacitors having two fully insulated terminals only, need not be marked.

6.2.2 Three-phase capacitors having electrically separate phases shall have the pairs of terminals corresponding to each phase marked A_2 and A_1, B_2 and B_1, and C_2 and C_1 respectively.

6.2.3 Two-phase three-wire capacitors shall have the two-phase terminals marked A_2 and B_2 respectively, and the neutral or common terminal marked N.

6.2.4 Two-phase four-wire capacitors shall have the pairs of terminals corresponding to each phase marked A_2 and B_2 respectively and the corresponding neutral terminals marked A_1 and B_1 respectively.

6.3 The capacitors may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard, Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

7. PERMISSIBLE OVERLOADS

7.1 Maximum Permissible Voltage

7.1.1 Capacitor units are not intended for prolonged operation at an rms voltage between terminals exceeding the rated voltage, excluding transient. Operation at a voltage not exceeding 1 05 V_n is permitted for I hour per day.

7.1.2 The maximum value of the peak voltage, including harmonics shall be $1{\cdot}6V_n$ for capacitors with rated frequency up to and including 60 Hz, and $1{\cdot}65\ V_n$ for capacitors operating at higher frequencies.

7.1.3 During transient conditions, the instantaneous voltage between terminals and container shall not exceed $2.\sqrt{2V_n}$.

7.1.4 Series capacitors shall be required to withstand the peak voltages of $2{\cdot}15\ V_n$ for 2 seconds which can occur during fault conditions.

7.2 Maximum Permissible Current — Capacitor units shall be suitable for continuous operation at an rms current not exceeding 1·25 times the rated current for capacitors with rated frequencies up to and including 60 Hz, and 1·35 times the rated current for capacitors operating at higher frequencies. This current includes harmonics, but excludes transients.

7.3 Switching — Capacitors shall be capable of being switched 'on' and 'off' up to 100 times on each working day by restrike-free methods.

NOTE — Switching is considered a transient condition (*see* **5 5.6** and **71**).

8. TESTS AND REQUIREMENTS

8.0 Standard Temperature for Testing — Unless otherwise specified, the standard ambient temperature range for testing shall be from 15 to 35°C.

8.1 Classification

8.1.1 *Type Tests* — The following shall constitute type tests:

a) Thermal stability test (*see* **8.2**);
b) Capacitor losses test (*see* **8.3**);
c) Measurement of capacitance (*see* **8.4**);
d) Measurement of capacitance as a function of temperature (*see* **8.5**);
e) Self-healing test (*see* **8.6**);
f) Voltage test (*see* **8.7**);
g) Test for internal discharge device (*see* **8.8**); and
h) Sealing test (*see* **8.9**).

8.1.1.1 For type tests three samples shall be drawn at random by the inspecting authority.

8.1.1.2 If any of the samples fails in the relevant type tests, the testing authority may call for fresh samples not exceeding twice the original number and subject them again to the test(s) in which failure occurred. If there is any failure in retest(s), the type shall be considered as not having passed the requirements.

8.1.2 *Acceptance Tests* — The following shall constitute the acceptance tests:

a) Capacitor losses test (*see* **8.3**),

b) Measurement of capacitance (*see* **8.4**),

c) Voltage test (*see* **8.7**),

d) Test for internal discharge device (*see* **8.8**), and

e) Sealing test (*see* **8.9**).

8.1.2.1 *Sampling plan and criteria for acceptance test* — Under consideration.

8.1.3 *Routine Tests* — The schedule of routine test shall be as follows:

a) Capacitor losses test (*see* **8.3**),

b) Measurement of capacitance (*see* **8.4**),

c) Voltage test (*see* **8.7**),

d) Test for internal discharge device (*see* **8.8**), and

e) Sealing test (*see* **8.9**).

8.2 Thermal Stability Test — This test is intended to demonstrate the thermal stability of the capacitor units under the cooling and electrical conditions described in **8.2.1** and **8.2.2**.

8.2.1 *Cooling Conditions*

8.2.1.1 The air-cooled self-ventilated capacitors shall be placed in an enclosure where the cooling air temperature is at the upper limit as stated on the rating plate. Throughout the test, the cooling air temperature shall be checked by means of a thermometer lagged so as to have a thermal time constant of approximately 1 hour. During the whole test, the difference between the measured cooling air temperature and the specified test temperature shall not exceed 2°C.

8.2.1.2 The air-cooled forced-ventilated capacitors shall be placed upright inside a vertical conduit which, for capacitors having a rectangular cross section, shall also have a rectangular cross section. The dimensions of the conduit should be sufficient to allow enough clearance on all sides for the flow of cooling air.

A clearance of 0·04 m on each side of the capacitor is suggested unless otherwise prescribed by the manufacturer. The conduit shall extend below the bottom of the capacitor container for about 0·4 m and above the top of the container for about 0·1 m.

The distance of the fan from the conduit shall be such (say 0·5 to 1 m) as to give good uniformity in the air speed. Preheated air shall be forced from below into the conduit the temperature of which shall be adjusted such that the upper limit of the cooling-air temperature stated on the rating plate is reached. The speed of the air midway between the wall of the conduit and the capacitor shall be measured.

The measurement of the inlet or outlet air temperature shall be made immediately below the bottom or above the top of the capacitor container and care shall be taken that this measurement is not influenced by radiation from the capacitor container.

The measurement of the temperature of the capacitor container shall be made near the top, below the level of the impregnant. The walls of the conduit shall be made of a thermally insulating material.

NOTE — It has been calculated that the error in the capacitor container temperature resulting from the use of conduit with thermally insulating walls instead of a similar energized capacitor placed beside the capacitor under test at distance equal to the clearance specified does not materially affect the result of the test.

8.2.1.3 For water-cooled capacitors two alternatives are provided:

a) The maximum water flow stated on the rating plate shall be kept constant throughout the test and the inlet water temperature shall be regulated by heating in such a way that the outlet water temperature is kept at the value stated on the rating plate.

b) The minimum water flow stated on the rating plate shall be kept constant throughout the test and the inlet water temperature shall be regulated to the maximum value stated in the rating plate.

8.2.2 *Electrical Conditions*

8.2.2.1 The test output shall be 1·20 times the rated output for capacitors with rated frequency between 40 and 60 Hz, and 1·33 times the rated output for capacitors with rated frequency above 60 Hz.

NOTE — For capacitors having rated frequency from 40 to 60 Hz, it is recommended that if the capacitor is selected from a batch, it should be the one with highest value of tan δ.

8.2.2.2 If the rated frequency of the capacitor cannot be realized, the test shall be made at a frequency as near as possible to the rated frequency. An appropriate correction factor for the reactive output in accordance with the applied frequency shall be agreed between the manufacturer and the purchaser. The test voltage shall be of approximately sinusoidal form.

8.2.3 *Test Duration and Criteria*

8.2.3.1 The capacitor shall be subjected to the cooling and electrical conditions specified in **8.2.1** and **8.2.2** for durations in accordance with Table 1.

TABLE 1 DURATIONS FOR THERMAL STABILITY TEST

TYPE OF COOLING (1)	TOTAL TEST PERIOD ON VOLTAGE (2)	FINAL PERIOD OF TEST DURING WHICH THE CAPACITOR SHALL BE IN THERMAL EQUILIBRIUM (3)
	hours	hours
Air-cooled self-ventilated	48	8
Air- or water-forced cooled	12	8

8.2.3.2 During the final period of test, the capacitor losses or the temperature of the capacitor container near the top shall be measured every 2 hours.

8.2.3.3 Throughout this period, the change in temperature inlet shall not be more than 1°C. When tan δ measurement is possible, it shall not vary by more than ± 10^{-4}. The sensitivity of measurement which shall not be worse than ± 10^{-4}.

If a greater change is observed, the test shall be continued until either equilibrium or breakdown occurs.

8.2.3.4 The capacitance measured after the test, related to the same temperature of the dielectric, shall not differ by more than 2 percent from the capacitance measured before the test If the capacitor is fitted with signalling or protective equipment, this equipment shall be operational but shall not be actuated during the test

8.3 Capacitor Losses Test

8.3.1 The capacitor losses shall be measured under the conditions given in **8.2.1** and **8.2.2** after thermal equilibrium is reached.

8.3.2 For capacitors with rated frequency between 40 to 60 Hz, the tangent of the loss angle shall be measured.

8.3.3 For air-cooled self and forced ventilated capacitors with rated frequency above 60 Hz, the losses shall be measured by a method to be agreed between the manufacturer and the purchaser.

8.3.4 For water-cooled capacitors with rated frequency above 60 Hz, the losses shall be calculated from the difference between outlet and inlet temperature of the water and the rate of water flow, and shall be calculated in accordance with **8.3.4.1.**

8.3.4.1 For water-cooled capacitors, the capacitor losses dissipated to the cooling water shall be calculated using the following formula:

$$\text{Loss} = P - (70 \times Q \times \Delta\theta)$$

where

P = active power in watts,

Q = rated of water flow in litres/minute,

$\Delta\theta$ = temperature-rise of the water in °C.

NOTE, — Water-cooled capacitors also dissipate some heat to the air from the sides of the container. Therefore, if the losses are to be measured fully, the capacitor should be surrounded with insulating material during the test. In most cases, however, it is sufficient to apply a correction to the losses dissipated by the water using a factor derived from previous experience.

8.3.5 *Requirement* — The capacitor losses shall not exceed the values declared by the manufacturer.

8,4 Measurement of Capacitance

8.4.1 The capacitance shall be measured using a method which excludes errors due to harmonics and accessories such as resistors, reactors and blocking circuits. The standard conditions for the test shall be a voltage between 0·9 and 1·1 times the rated voltage and a frequency between 40 and 60 Hz.

Measurement at lower voltages and rated frequency may be made by agreement between the manufacturer and the purchaser.

8.4.2 *Requirement* — The total output computed from the measured capacitances, the rated voltage and the rated frequency shall not differ from the rated output by more than:

a) ± 10 percent for units, and banks with up to and including 9 units, and

b) $^{+10}_{-0}$ percent for banks with 10 or more units.

The sum of the individual capacitances of a multi-terminal capacitor unit shall be within the tolerance prescribed for capacitor units.

8.5 Measurement of Capacitance as a Function of Temperature — When agreed between the manufacturer and the purchaser, the dependence of the capacitance on the temperature may be measured.

The capacitor shall be subjected to the electrical condition given in **8.4**.

8.6 Self-Healing Test — This test is applicable to self-healing metallized dielectric capacitors.

8.6.1 The capacitor shall be subjected for 10 seconds to an ac voltage of 2.15 V_n or alternatively a dc voltage of 4 3 V_n at the discretion of the manufacturer. If fewer than five breakdowns occur during this time, the voltage shall be increased slowly until five breakdowns have occurred since the beginning of the test. After this the voltage shall be decreased to 0 8 times the initial value (that is, 1·72 V_n for the ac test and 3·44 V_n for dc test) and maintained for 10 seconds.

8.6.2 One breakdown shall be permissible after decreasing the voltage provided that no further breakdown occurs within a time of 10 seconds from this breakdown.

8.6.3 Before and after the test, the capacitance shall be measured and there shall be no significant change in its value.

NOTE 1 — Breakdown during the test may be detected by an oscilloscope or by accoustic or high frequency test methods. Special attention shall be given to the sensitivity of the instrument used.

NOTE 2 — When comparing the results of capacitance measurement obtained before and after the test, the following two factors shall be taken into account:

a) The reproducibility of the measurement, and

b) The fact that an internal change in the dielectric may cause a small change in the capacitance without any detriment effect on the capacitor.

8.7 Voltage Test

8.7.1 *Test Between Terminals*

8.7.1.1 Every capacitor shall be subjected for 10 seconds to either test (a) or test (b) specified below:

a) A dc test, the test voltage being $V_t = 4{\cdot}3\ V_n$.

b) An ac test, the test voltage being $V_t = 2{\cdot}15\ V_n$.

The ac test shall be carried out with substantially sinusoidal voltage at a frequency between 15 and 100 Hz.

For self-healing metallized dielectric capacitors, self-healing breakdowns are allowed during the test.

8.7.1.2 *Requirement* — Before and after the voltage test, the capacitance shall be measured and there shall be no significant change in the values.

NOTE 1 — To avoid transient, the test voltage shall not be switched on at its full value but shall be increased gradually. The 10 seconds time shall be counted from the moment the full test voltage has been reached.

The dc voltage may begin at zero and reach the full value in 5 seconds. The ac voltage may begin at half the test voltage and reach the full value within 5 seconds. The frequency of testing shall be 50 Hz and the discharge device shall be disconnected during the test if it is not internally connected.

NOTE 2 — The discharging current shall be limited to ten times the rated current. After discharging, the terminals may be left short circuited together for at teast 1 hour.

NOTE 3 — Capacitors according to this standard are normally single-phase units. If polyphase or other connections are used, the test connection and voltage shall be such that the dielectric stress in the capacitor element is at least as great as that which would be obtained in the testing of single-phase units.

NOTE 4 — While testing one section, other sections may be short-circuited together throughout and after this test.

8.7.2 *Test Between Terminal and Container*

8.7.2.1 Every unit with all terminals insulated from the container shall be subjected for 10 seconds to a test between terminals (jointed together) and the container with a substantially sinusoidal ac voltage V_t having a frequency between 15 to 100 Hz and an rms value of:

V_t = 2·15 × rated insulation voltage, with a minimum 2 000 V.

The test voltage V_t shall not be lower than the power-frequency ac test voltage of the plant to which the capacitor is to be connected.

NOTE — If the insulation between terminals and container is subjected to an ac voltage with superimposed dc voltage, the value of the rated insulation voltage in the above formula shall be at least the peak value of the total voltage divided by $\sqrt{2}$.

8.7.2.2 *Requirement* — There shall be no breakdown of voltage during the test.

8.7.3 *Test Between One Section and Remaining Sections*

8.7.3.1 All terminals of the remaining section are shorted together and connected to the housing. Both the terminals of the section under test are shorted together and test voltages are applied between this and the container.

8.7.3.2 *Requirement* — There shall be no breakdown of voltage during the test.

8.8 Test for Internal Discharge Device — The resistance of the internal discharge device, if any, shall be checked either by a resistance measurement or by measuring the self-discharging rate (*see* **5.1.2**) This test shall be carried out after the voltage test (*see* **8.7.1**).

8.9 Sealing Test — The method of testing shall be as agreed between the manufacturer and the purchaser. Appendix A provides guidance for carrying out this test.

9. INSTALLATION AND OPERATION

9.1 The general guidelines for the proper installation and operation of the capacitors is given in Appendix B.

APPENDIX A

(*Clause* 8.9)

GUIDELINES FOR SEALING TEST

A-1. The inside temperature of a capacitor shall be raised to T_{max} + 10°C. If T_{max} is not given in the rating plate, temperature reached under the thermal equilibrium tests may be accepted as $T_{max.}$ Leakage of oil shall usually be ascertained after 1 hour of reaching T_{max} + 10°C.

A-2. The cooling ducts should be pressure tested with oil at 30 bar for 1 minute. The pressure should hold and there should be no traces of leakage or seepage of oil.

APPENDIX B

(*Clause* 9.1)

GUIDELINES FOR INSTALLATION AND OPERATION

B-1. GENERAL

B-1.1 Unlike most electrical apparatus, shunt capacitors whenever energized operate continuously at full load during service.

The operation of a capacitor at a voltage, current or temperature in excess of that for which it is designed will seriously shorten its life.

In comparison with power capacitors covered by IS : 2834-1964* the concentration of power in banks of capacitors covered of this specification is so high and the rated voltage so low that special problems arise due to the heavy currents to be carried and the large amount of heat to be dissipated.

Problems also arise in switching at high frequencies, measurement of temperatures, etc. It is, therefore, necessary to check the operating conditions carefully.

The following information on installation and operation relates only to the most important points to be considered. In addition, the instructions of the manufacturer should be followed.

B-2. MEASURES TO OBTAIN ADEQUATE COOLING

B-2.1 Air-Cooled Self-Ventilated Capacitors — The capacitors should be mounted with a ground clearance and a distance between capacitors of at least 0·05 m in such a way that the cooling air may enter the air gaps between the capacitors and the floor.

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*Specification for shunt capacitors for power systems.

If several rows of capacitors are arranged one above the other, it is important to check that the maximum permissible temperature of the cooling air is not exceeded even for the uppermost row.

It should be recognized that adequate ventilation of the room or building should be available.

B-2.2 Air-Cooled Forced-Ventilated Capacitors — For air-cooled forced-ventilated capacitors, the effectiveness of the cooling air depends on the temperature and velocity of the air flowing along each capacitor. Therefore, the designer of the capacitor plant should ensure that the minimum air velocity which is required in the gaps is attained.

It is necessary far the capacitor manufacturer to declare the losses of the capacitor under normal operating conditions.

B-2.3 Water-Cooled Capacitors — The maximum permissible temperature of the cooling water flowing into the capacitors (inlet temperature) or flowing out from the capacitors (outlet temperature) should not be exceeded [*see* **6.1.1**(h)] and the rate of flow of the cooling water should never fall below the minimum permitted value [*see* **6.1.1**(h)].

If the water ducts of several capacitor units are connected in series, these conditions should be fulfilled for the last unit in the direction of the water flow.

As the cooling water supply will not be uniform at all times, the user of the capacitor plant should ensure that the limit for the outlet temperature of the cooling water is not exceeded.

Special attention is drawn to the following:

a) While temporary transporting and installing, the cooling ducts should be emptied. Before switching on the capacitors, the liquid flow shall be established at the specified rate and conditions. This can be ensured through a flow rate actuated safety switching relay; and

b) Cooling water or liquid should not be restricted by:

   1) an obstruction or a severe bend in the cooling pipe or hose, and

   2) being frozen to a solid stage at freezing ambient temperature.

   The limit for the air temperature should also not to be exceeded. The capacitor may be equipped with a temperature sensor which can be used for overload protection.

B-3. CHOICE OF THE RATED VOLTAGE CURRENT AND OUTPUT

B-3.0 In principle the rated voltage of the capacitor should be equal to the actual services voltage of the network or system to which the capacitor is to be connected account being taken of the influence on the voltage of the capacitor itself. In certain network or system considerable difference may exist between the actual and nominal voltage, details of which should be supplied by the purchaser, so that due allowance may be made by the manufacturer. This is a matter of considerable importance for capacitors. Since their performance and life may be adversely affected by an undue increase in the stress on the capacitor dielectric.

B-3.1 When capacitors work with varying voltages and frequencies:

a) their load limits as given in **7.1** are not exceeded, and

b) special consideration may be given to series capacitors carrying fixed currents where voltages across series capacitors shall arise as the frequency falls down.

B-4. CAPACITORS FOR FREQUENT SWITCHING ON LOAD

B-4.1 In **7.3** the maximum permissible number of switching operations each day is stated. If this quantity is to be exceeded a special design should be agreed between the manufacturer and the purchaser.

B-5. CHOICE OF SWITCHGEAR AND SWITCHING METHODS FOR SWITCHING ON LOAD

B-5.1 All main connections, contactors, circuit-breakers and fusegear used with the capacitor shall be designed to carry continuously a current of 1·15 times the capacitor current at rated voltage and rated frequency (*see* **7.1**). In addition control gear associated with capacitors is subject to more onerous conditions of use than that on similar apparatus carrying other ac loads of equivalent kVA. It is important to remember this when selecting the appropriate rating of switchgear and fusegear. The manufacturers of such equipment should be informed of the purpose for which it is to be used.

The duty imposed on the switchgear and fusegear used with capacitors is particularly onerous for following reasons:

a) At the instant of switching, a transient current may flow which may be of the order of 20 times the normal current. For this reason it is particularly important that switches or contactors controlling capacitors should close with a minimum of bounce on the contacts as otherwise there may be a danger of contact welding.

b) High overvoltage transients can occur when capacitors are disconnected by switching devices which allow restriking of the arc. It is, therefore, necessary to ensure that the switching devices do not allow restriking to occur.

c) The switch and fuse have to carry continuously the full rated current of the capacitor at all times when the capacitor is in circuit.

d) At light loads when the voltages may be higher than normal, the capacitor current shall be increased accordingly.

e) If harmonics are present in the supply voltage, the capacitor current shall be increased.

For switching capacitors, only switchgear which is capable of performing restrike free operations should be used. However even with switchgear which has been carefully chosen and correctly adjusted before use, restrikes may occur after a number of operations, if the switchgear is not regularly serviced. Very high switching surges then occur and one unfavourable switching operation may cause breakdown of a capacitor.

Therefore, regular servicing is necessary.

For high frequency currents, however, carefully selected and serviced switchgear of normal design is not able to switch off a capacitor without restrike, if the operating time of the switchgear is equal to or longer than the duration of a half-cycle of the frequency of the power supply.

To avoid overstressing of capacitor and plant, instantaneously operating switchgear, such as thyristors or normal switchgear in combination with additional measures within the switched circuit should be employed,

B-5.2 The switching and protective devices and their connections should be designed to carry the maximum current occurring under any conditions of use.

If these devices are designed for normal use at 50 or 60 Hz, an appropriate derating factor should be considered.

B-5.3 If a capacitor is to be switched in parallel with other capacitors already energized, the switching and protective devices and the connections should be capable of withstanding the electrodynamic stresses which are caused by the transient overcurrent which may occur at switching-on.

If the electrodynamic stresses are likely to be excessive, special precautions should be taken to reduce these transient effects, such as resistance switching or insertion of reactors in the supply circuit to each section of the capacitor bank.

B-5.4 Corresponding to **5.1.3** the capacitors are designed to be switched on in almost discharged conditions. If the capacitors are switched at very short intervals, discharge resistors complying with **5.1.2** discharge the capacitors too slowly. In this case, the designer of the plant should determine the shortest time between switching operations and choose **a** discharge device suitable for this time.

B-5.5 For capacitors with fuses, it is necessary to ensure that the transient current occurring at the operation of the switch does not exceed the withstand current of the fuses.

This requirement applies also to single capacitors which are switched in parallel with a capacitor bank which is permanently connected in circuit.

Fuses for short-circuit protection should have a breaking capacity appropriate to the prospective current of the circuit. Care should also be taken to ensure that the transient switching current is sufficiently far below the corresponding short time fusing current of the fuse, to avoid the excessive momentary temperature which such currents can cause in the fuse.

B-5.6 Operation with Varying Frequency — If capacitors are intended to be operated at varying frequencies but are not designed and marked for this special purpose, then care should be taken that the permissible overloads stated in **7** are not exceeded. Special attention should be paid to capacitors intended for operating in series with other components, as at constant current the voltage across the capacitor varies in inverse proportion to frequency.

NOTE — When designing the plant, a graph should be obtained from the capacitor manufacturers, showing the limits of actual rms voltage and rms current plotted against frequency To enable the manufacturer to give this information, the designer of the plant should state the ordinal number of the most important harmonic and its highest expected magnitude.

B-5.7 Choice of Rated Insulation Voltage of the Capacitor Bank — For capacitors intended to be operated in parallel with the plant, the rated insulation voltage is equal to the rated voltage V_n. For capacitor banks in parallel with the plant, in which π similar capacitor units or groups of units are connected in series and where all containers of the units have the same potential, the rated insulation voltage is equal to $n \times$ rated voltage.

B-5.8 Capacitor Connected in Series — When connecting in parallel with the plan capacitor bank in which single units or groups of parallel-connected units are connected in series, care should be taken that the capacitance values are as nearly as possible equal to each other in order to ensure that the voltage across each unit should not exceed the rated voltage.

B-5.9 Connecting Leads — Connecting leads should not overstress the bushings mechanically. Additional losses caused by the unequal distribution of current over the cross section of the connecting leads should be taken into account, especially for frequencies higher than power frequencies.

B-5.10 Electrical Leakage Along Water Supply — Live parts of water ducts, for example, water hose connectors shall be arranged in such a way that dangerous voltages cannot be transmitted to conducting parts of the plant which may be touched. Also care shall be taken that no potential displacement is caused in the plant by the voltage drop along the water hoses.

This precaution applies particularly to shunt capacitor banks where the units are connected in series. Possible increase in conductivity of the water should be taken into account.

B-5.11 Post Insulators — Post insulators for capacitors which are used to support the capacitor when the container is not at earth potential shall be designed according to the highest voltage that can occur across them. If the voltage distribution between the capacitors and the post insulators is uncertain, the post insulators should conform to the full insulation voltage of the plant to which the capacitors are to be connected.

B-5.12 Danger of Freezing for Water-Cooled Capacitors — Damage to water-cooled capacitors result from water freezing in the duct.

Therefore, care should be taken that the water in the cooling circuits does not freeze during stoppages of the plant. Water should be completely removed before capacitors are stored or transported.

INDIAN STANDARDS ON POWER CAPACITORS

IS:	
1885 (Part XLII)-1977	Electrotechnical vocabulary: Part XLII Power capacitors
2834-1964	Shunt capacitors for power systems
2993-1975	Motor capacitors (*first revision*)
9251-1979	Capacitors for inductive heat generating plants operating at frequencies between 40 and 24 000 Hz

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous Intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg. m/s^2
Energy	Joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T =1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	Siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1N/m^2

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 26 60 21, 27 01 31 **Telegrams : Manaksanstha**

Reginal Offices :		Telephone
Western : Novelty Chambers, Grant Road	BOMBAY 400007	37 97 29
Eastern : 5 Chowringhee Approach	CALCUTTA 700072	23-08 02
Southern : C. I. T. Campus, Adyar	MADRAS 600020	41 24 42
Branch Offices :		
'Pushpak', Nurmohamed Shaikh Marg, Khanpur	AHMADABAD 360001	2 03 91
'F' Block, Unity Bldg, Narasimharaja Square	BANGALORE 560002	2 76 49
Gangotri Complex, Bhadbhada Road, T.T. Nagar	BHOPAL 462003	6 27 16
22 E, Kalpana Area	BHUBANESHWAR 751014	5 36 27
Ahimsa Bldg. SCO 82-83, Sector 17C	CHANDIGARH 160017	2 83 20
5-8-56C L.N Gupta Marg	HYDERABAD 500001	22 10 83
D-277 Todarmal Marg Banipark	JAIPUR 302006	6 98 32
117/418 B Sarvodaya Nagar	KANPUR 208005	8 12 72
Patliputra Industrial Estate	PATNA 800013	6 28 08
Hantex Bldg (2nd Floor), Rly Station Road	TRIVANDRUM 695001	32 27

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